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ABSTRACT

The least understood of complex systems is that which produces educated people. Superficially, many key elements of a manufacturing organization are part of the system: a product, product tolerance limits, methods for assessing product deviation, and a feed-back system for making compensatory adjustments. In layman's terms these elements are: educated youth, educational goals or objectives, performance tests, and a reporting system. Their existence has led to an attempt at applying a wholesale systems framework to education with mixed results. Reasons for the lack of success in this attempt is analysed in this study. It is suggested that system analysts, rather than modeling the total system, should focus on those aspects of education which can be systematized. Such aspects are: resource allocation, scheduling, prediction systems (research and evaluation), and data bank systems. It is theorized that two conditions must be met to enable a systems approach to be successful in an educational application: (1) The designers must exhibit a fine sensitivity to the fact that schools are political entities, and (2) the system must be focused at the level of the individual student. The implications of these assumptions are discussed. (Author)

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AN ANALYSIS OF SYSTEMS APPLICATIONS IN EDUCATION

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An Analysis of Systems Applications in Education[1]

The large and some would say vast, recent expenditures for American education, e.g., 36 billion dollars in 1964, have led inexorably to demands that educators show the value of their activities. The catchword is now "accountability." To underscore the seriousness of the concern and indeed the lack of confidence in the current educational enterprise, most program grants have mandated evaluation components. Faced with this situation, most practicing educators, not having an internal evaluation capability within their school systems, turned to the research community for help. University researchers became involved, and in the process discovered that the methodologies at their command were completely inadequate. They were involved in a different area, which has come to be termed "evaluation," and Egon Guba (1969) expressed the frustrations of researchers with his statement that "evaluative inquiry does little more for a researcher than to give him an opportunity to disgrace himself while not really serving his purposes."

Faced with a pressing need, educators began searching for a new approach that would serve several functions. First of all, the approach would have to provide evaluative data on functioning programs. Second, it would have to be able to relate such data to cost factors (this function became critical as more and more school bond issues were turned down by the taxpayers and state legislators seemed to be more interested in their own salaries and expense accounts than in education). Third, the approach would have to be capable of making predictions on the effectiveness of changing program components. Such functions seemed ready made for the group of engineers which Boguslaw (1965) has called the "new utopians," more familiarly, systems scientists.

There were several other reasons why the systems approach seemed applicable, not the least of which was that it was being pushed by the Federal funding agencies.

Beyond this, however, were such rationales as: 1) the approach used computers, and the apparently large storage capacities of such machines seemed to be necessary to handle the complexities of the educational process; 2) the field had a reputation for successfully dealing with enormously complex operational systems, e.g., the space effort; 3) finally, many educators became convinced that it was valid to see education as a special case of a manufacturing system.

Thus, it has become somewhat commonplace to speak of elements of the educational enterprise in manufacturing terms. For example, educated youth is taken to mean the product of an educational system. Similarly, we can view educational goals as being a statement of the tolerance limits for the system, performance tests as the methods for assessing deviation from the limits, and presumably report cards and data banks are the ways in which feedback for assessing total system performance is accomplished as well as providing stockholder (taxpayer) reports.

Given the enormous problems of education and a certain superficial similarity to a manufacturing system, it was not long before educators were deluged with a new breed of enterpreneur: the systems scientist and the hardware salesman, often if not the same person then one so similar that they appeared as Tweedle-dum and Tweedle dee. It was no accident that the software of the "new utopian" was dependent upon an investment in some rather expensive equipment--often a computer that the school system found it didn't need, couldn't program, and couldn't afford.

The services proposed, and sometimes even provided, by such persons have taken one of two basic forms. The first is exemplified by two studies, one done for the Kentucky school system (Miller, 1968), and one done on Project Head Start (Watts and Horner, 1968). This approach may be fairly termed "old wine in new bottles." The old wine is the familiar multiple regression, and sometimes, multiple canonical, methodology; the new bottle is the adding of cost information and the calling of the whole pursuit "systems."

The second form is exemplified by the work of Sisson (1967), who is attempting no less than a modeling of the entire educational process. In this approach, the systems analyst attempts to predict achievement (never mind how it is measured), from a knowledge of some rather simple input parameters (in Sisson's case, staff per student, material per student [in dollars], space allocation, community relations effort [in dollars] and parental education). This approach differs from the multiple regression method in that bivariate normality and linearity of regression are not assumed to be the only relationship holding between variables. The writing of functional equations which reflect other kinds of relationships, e.g., exponential, is certainly an improvement over the regression approach if for no other reason than the fact that real systems are distressingly nonconformist with regard to Gaussion distributions. Unfortunately, the unreliability inherent in most measures of human, let alone system performance, requires that constants be added to the equations in order to bring the plotted functions into line with real data. And, as one wag commented with regard to Clark Hull's use of constants, "an equation with two constants can be made to describe an elephant, add a third and it will wag its tail."

The modelers, at least those in the Sisson tradition seem also to assume that feedback of information on system performance occurs with a zero delay time. We say, "assume," since few if any mathematical equations used in these educational applications include such functions. However, it takes no great insight into the ways in which educational systems function to note how much inertia there is in responding to knowledge that the "system"is not functioning properly. Often, by the time action has been taken, the problem has become exacerbated to the point that the solution adopted has little (if any) real effect. In modeling real educational systems, the feedback system must not only have an extraordinarily long time constant, but the loop must include delays and modifications of input

arising from the varied responsibilities of decision makers at several levels. The problems of modeling such a loop are yet to be understood, in contrast to ordinary manufacturing operations where decision making functions are centralized and response to a problem can be timely.

If anything, an educational decision maker needs to develop a precognitive (Krendel and McRuer, 1960) mode of operation. That is, he has to be able to anticipate the system's performance and act ahead of the predicted changes. While methods for the presentation of feedback leading to such modes of operation have been worked out for certain skills (e.g., flying an airplane or driving a car), they have yet to be developed for large and complex systems. Sisson-like models, while they may describe, more or less accurately, relationships between input and output variables at a given time, become progressively more and more out of phase, or inaccurate, as time passes, because they fail to take account of the open-loop-like characteristics of the educational system. Until such considerations can be built into the model, these approaches will be inaccurate guides to decision making.

In any case, these two approaches are focused at the administrative level and bridging the gap to individual students is extremely difficult. There can be little disagreement with Thomas Watson (1969), IBM's President, in his statement that the critical problem of education is how to articulate the functioning of a complex system with the needs of the individual student. It is at this level that we see a need to focus the major impact of the systems approach, and it is to this problem that the remainder of this paper is directed.

To provide adequate management of an educational system, and thereby increase the probability of making intelligent and informed decisions, the educational administrator or decision maker needs to have the following (Provus, 1969):

(1) A statement of goals.

(2) A plan of operation.

(3) A statement of support systems.

(4) An evaluation system for monitoring the installation and operation, with provision for feedback.

Each of these is critically important for determining the degree of success of a total educational program. However, the fourth point (an evaluation monitoring system) is of particular importance in the design and construction of a system which is useful in predicting individual performance. Obviously, an evaluation structure that provides continuous monitoring and feedback at all levels of the educational process is needed at those levels which have heretofore been ignored.

The key attribute of such a system would seem to be the introduction of an integrated set of man/machine programs and functions which can actively monitor relationships among the three major factors (Miller, 1968) of any educational system at both the student and at the administrative level. These major factors are: (1) input factors, including community and socio-economic variables that have been traditionally incorporated into system evaluations; (2) process factors, including a variety of school and instructional variables only a few of which have been analyzed; and (3) output factors, including a number of student achievement and school achievement variables that have generally been overlooked or ignored in system studies, e.g., affective variables.

These factors are reflected by a series of propositions which grow out of a particular view of education and out of the role systems analysts might assume in helping educators achieve their goals:

(1) Education is concerned with assisting everybody to develop, as fully as possible, the knowledge and skills needed to function effectively in a rapidly changing society. Effective participation involves both the individual's need for fulfillment and the society's (system's) need for stability and cohesion.

(2) At any point in the educational system, the individuals to be taught will differ in their capacities, interest, and backgrounds. To be effective, educational programs must be adjusted to take account of these differences.

(3) While providing for individual differences, the educator must recognize that the goals of education are both individual and social.

(4) While in one sense the core of an educational program is instructional in content, in a broader sense, provision must be made for guidance and evaluation. Effective instruction (education) implies effective guidance (decision making) based on continuous evaluation (system feedback).

(5) In a diverse and decentralized school system (such as the USA), details of organization and procedure will differ widely from school system to school system. It is the responsibility of analysts to provide for these differences and of administrators in each educational unit to determine details.

(6) Individual schools and school systems must be provided with services that will increase the efficiency of their efforts to monitor their educational programs--to the end that necessary decisions are informed and that educational programs may be improved.

(7) If provisions for evaluation are to be effective, they must be based on a sound conception of how individuals learn and how evidence of learning may be assembled and analyzed. Therefore, study of both the learning process and the evaluation process is a legitimate and required function of systems packages.

It is within the framework suggested by these seven propositions that an outline for the development of a systems evaluation package, geared on the one hand to the needs of individuals and on the other to the more global needs of the school system, can be described.

At the level of the individual, one promising system application would take advantage of the computer's capacity to monitor the performance of a great number of students and to select subsequent units of instruction on the basis of each student's response to questions embedded in previous instructional sequences and, at educational decision points, retrieve up-to-date performance records for the teacher or counselor. Such records may, in time, assume some of the functions now served by

external examinations. Thus, the teaching and testing functions, which have never been as intergrated as most theorists say they should, are likely to come even closer together in the future. It should be noted that we are not referring here to CAI, but to what is called computer managed instruction. The functions described above might well be carried out by systems modules responsible for student record keeping and central predicition.

At the level of the school system, educational administrators are likely to find themselves needing methods for collecting and summarizing data bearing on the over all functions of an educational system of ever-increasing complexity. In addition to information about the status of individual students at periodic intervals, those responsible for operating the schools need information about a variety of variables--characteristics of the staff, the nature of the tax base, a profile of community values, etc.--which should be taken into account in attempts to understand and evaluate the functions of the school system. System modules for resource allocation, scheduling, and the like might best carry out these aspects of the system evaluation. It is clear that only through understanding evaluation requirements at this level and articulating them with the individual requirements specified above, can a system package be created that will satisify very real economic constraints as well as to sensitively adjust educational oppportunities to a wide variety of individuals.

The two levels of consideration outlined above, then, suggest a range of evaluation concerns: from the evaluation of the individual to the evaluation of the educational systems which act upon the individual, or within which the individual interacts. The ability of the systems analyst to provide the necessary methods and the ability of the computer to facilitate complex analyses of the many variables, offers promise that the day is not far off when a usable systems evaluation may be operational.

Another very practical but important need is to avoid raising unrealistic expectations about what the new technology, particularly computers, can accomplish in a relatively short time period. There are no quick and easy solutions, and long-range commitment to systems applications is needed. Realistic expectations about what computers can do are vital, for example, analysts have not been as careful as they might to turn over to the computer only those tasks for which the machine is best suited and only those decision alternatives for which a completely defined and logical series of actions exist. Rather, they have all too often delegated to the computer system responsibility for directing and/or forcing decisions on the basis of faulty or incomplete information (Townsend, 1970). What is needed to resolve this dilemma is a totally intergrated system (perhaps designed on a modular basis) which can completely adapt to all current educational procedures and processes and which is designed so as not to preclude modification to satisfy future needs and demands. Development of this system will require time and extended effort.

Before the system that we have described can be made operational, some rather important practical problems will have to be overcome. These problems are illustrated in the experience of one of the larger United States school systems in attempting to apply system concepts at all levels of its functioning. This program has been a long range effort which started three years ago, and, at this writing, the program has not yet come to full fruition. Four critical problems which have hampered the development of a full systems approach:

First, it has proved extremely difficult to get educators to state specific objectives in measurable terms. Sometimes, this problem has been made worse by the failure of the systems people to adequately communicate to educators what is needed.

Second, it has been difficult to get educators to adhere to the system. There are really two problems here. The first is that educators work in a

political environment where decisions must be made to assuage this or that pressure group. The second problem is that decision making information has often not been timely. The last situation arises when hardware is installed without sufficient software and personnel backup.

Third, present methods of relating input to output do not provide accurate forecasting. The complexities of the educational process, particularly in a large urban school system, are such that no simple model will suffice.

Finally, even when adequate evaluation methods have been available, it has been difficult to convince program managers that research and evaluation personnel should be involved in project development.

What these reports suggest is that before any system can work in a real setting, some rather serious thinking has to be given to the problem of educating both the designer and the user. To some extent, this is a problem that faces any systems designer. But, in an educational system which operates under considerable political constraint, at a level of complexity which is staggering, and in which many basic research questions are yet to be answered, the practical problems are not trivial.

We started this paper by being critical of the systems analyst and the traditional educational researcher. This was deliberate for it has been clear for some time that neither were sufficiently aware, nor concerned, about the practical problems faced by the educator. It is our feeling that the failure of "research" and "systems" to cure the ills of education has been partially due as much to a failure of the physician to understand the problem as the patient's reluctance to take the cure. The amount of money, on both the Federal and Local levels, wasted on "systems" and research programs would astound and dismay most of us. The time is propitious for us, systems analysts and researchers alike, to seriously consider what it is we are about--and how our efforts can contribute to our improvement in the quality life for all of us.

We close this monograph with two quotes; both of which come from persons

actively engaged in the business of systems design, at two quite different levels.

The first, Robert Boguslaw is a systems analyst of some note. The second, Thomas Watson, Jr. needs no identification.

> And perhaps the most notable difference to be found between the classical system designers and their comtemporary couterparts (system engineers, data processing specialists, computer manufacturers, and systems designers) consists precisely in the fact that the humanitarian bent has disappeared. The dominant value orientation of the utopian renaissance can best be described as 'efficiency' rather than 'humanitarianism.'
>
> (Boguslaw, 1965, Page 202)

and,

> In our recommitment to (humanitarian) values...lies the key to technology's good use in our time--its service to the supreme end of education, the fulfillment, freedom and happiness of the individual human being.
>
> (Watson, 1968, Page 189)

Footnote

Portions of this monograph are based on an invitational paper, "The educational system as a system," presented at the International Conference on Production Research, held as the University of Birmingham, England, on April 5 through 10, 1970. The ideas expressed here are those of the authors and do not necessarily represent positions of their respective organizations. Presentation of this paper was made possible by Grant GZ-1528 from the National Science Foundation to the first author.

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